Smart Dental Fillings with Ruthenium Nanoparticles-enhanced Photobiomodulation Therapy for Pulp-Dentin Regeneration

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Statement of Purpose: Dental pulp trauma, especially in deep carious lesions, is a formidable challenge in clinical dentistry. The use of calcium hydroxide has had a long clinical history as a biocompatible liner and hermetic restorer. Other options include Mineral Trioxide aggregate and nanocalcium silicate that are often still very expensive. A new class of smart dental biomaterials and biotechnologies are enabling regenerative dentistry.[1] The use of low dose laser treatments, termed Photobiomodulation (PBM) therapy, has been shown to promote dentin formation.[2] Ruthenium [Ru(bipy)3]2+ is a red-emitting chromophore (620nm) that absorbs strongly at (450 nm) blue light, a wavelength commonly used for light curing dental composites.[3]

Objectives: To develop a Ruthenium-based dental biomaterial system to promote dentin induction by odontoblasts using PBM therapy

Methods: Polylactic-coglycolide (PLG) microspheres containing ruthenium (Ru-PLG) were synthesized using a double emulsion technique. Microspheres were analyzed using SEM-EDS for effective composition. Tissue culture plates were coated with the Ru-PLG microspheres, washed and UV sterilized followed by seeding with an odontoblast, MDPC-23 cell line.

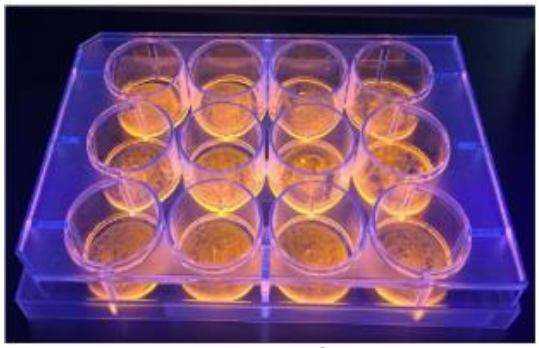

Figure 1: PLGA $[Ru(bipy)_2]^{2+}$ in a 12 well plate illuminated by a blue (~450 nm) light before cell insertion.

Plates were treated with blue and red LED and near-infrared (NIR) laser. After 24 hours, cells were lysed and assessed for total protein with Bradford's assay and analyzed for mineralized tissue differentiation using Alkaline Phosphatase (ALP) enzyme assay.

Results: SEM-EDS analyses demonstrated inclusion on Ruthenium in PLGA microspheres (Figure 1). Average microsphere diameter ranged from 25-100u.

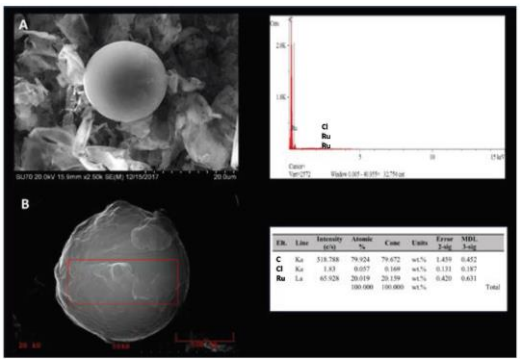

Figure 2: (A) SEM (20kV) and (B) EDX of PLGA $[Ru(bipy)_2]^{2+}$

We observed significant odontoblastic mineralized differentiation with blue LED assessed with normalized ALP levels ($p < 0.05$). Treatments with Ru-PLG and Red LED treatments also demonstrated a similar significant increase in normalized ALP levels indicating their ability to promote mineralized differentiation in MDPC-23 cells ($p < 0.05$).

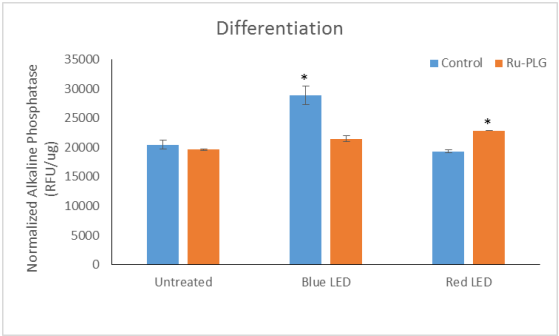

Figure 3: Normalized ALP values in MDPC-23 cells plated on PLG-Ru coated plates.

Conclusions: Several technologies are enabling a new era of biomaterials for pulp-dentin regeneration.[4] Our results demonstrate the functionality of the Ru-PLG systems for PBM treatments beyond the initial clinical pulp exposures. These novel light-emitting biomaterials could enable sustained PBM therapy beyond initial clinical pulp exposure and treatments.

References:

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